Committee on Earth Observation Satellites

Ambitions of the CEOS AC-VC GHG Whitepaper

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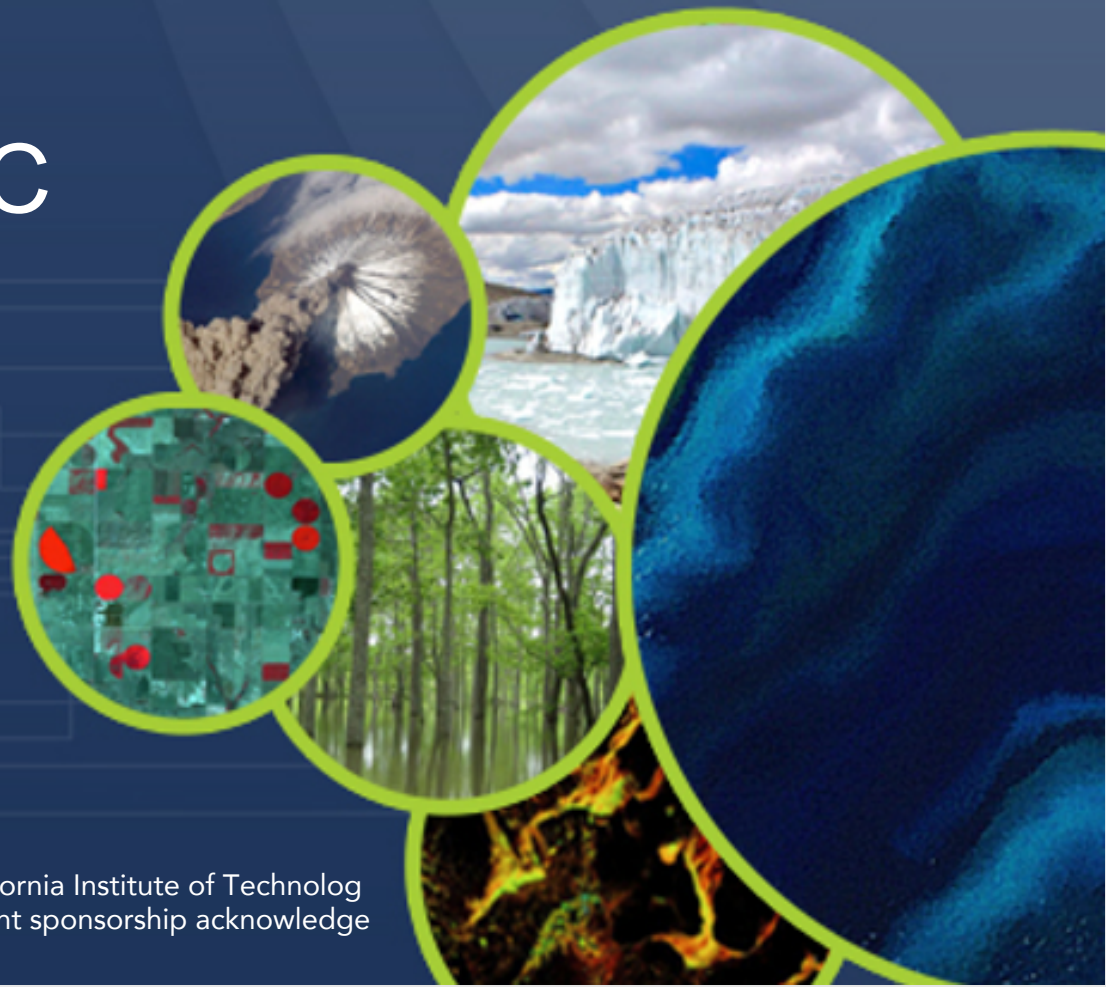
for the CEOS AC-VC Greenhouse Gas Team

June 9, 2019



Objectives

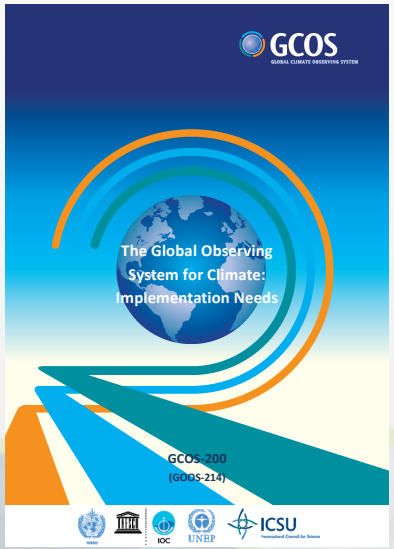
- Background and international Context

- An architecture for GHG observations
  - Operating and planned space-based sensors
  - The operational constellation

- Role of atmospheric CO_2 and CH_4 inventories in the Paris Agreement

- Approach: A prototype atmospheric CO_2 and CH_4 inventory to support the 2023 Stocktake

Background
Action T71 from GCOS IP 2016



Action T71:	Prepare for a carbon-monitoring system
Action	Preparatory work to develop a carbon monitoring system to be operational by 2035; Development development of comprehensive monitoring systems of measurements of atmospheric concentrations and of emission fluxes from anthropogenic area and point sources to include space-based monitoring, in situ flask and flux tower measurements and the necessary transport and assimilation models
Benefit	Improved estimates of national emissions and removals
Time frame	Initial demonstration results by 2023 – complete systems unlikely before 2030
Who	Space agencies
Performance indicator	Published results
Annual cost	US$ 10–100 billion

- CEOS and CGMS will define an architecture of space component elements to address the requirements of a CO_2 and GHG monitoring system , …

COP-23/SBSTA-47

United Nations

Framework Convention on Climate Change

FCCC/SBSTA/2017/L.21

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Original: English

Subsidiary Body for Scientific and Technological Advice
Forty-seventh session
Bonn, 6–15 November 2017

Agenda item 8
Research and systematic observation

Research and systematic observation

9. The SBSTA recognized the progress made by the satellite community (see para. 4(e) above), in close collaboration with GCOS, in the development of the essential climate variable inventory.[16] It noted the usefulness of the essential climate variable inventory for climate services. It invited CEOS and CGMS to report on progress at future sessions of the SBSTA, as appropriate.

10. The SBSTA noted with appreciation the information provided in the submission referred to in paragraph 4(a) above on the Global Framework for Climate Services (GFCS).[17] It invited WMO to report on progress in implementing the GFCS at future sessions of the SBSTA, as appropriate.

11. The SBSTA invited the UNFCCC secretariat to communicate with the WMO secretariat, including with regional centres, to inform work on climate services.

12. The SBSTA noted the increasing capability to systematically monitor greenhouse gas concentrations and emissions, through in situ as well as satellite observations, and its relevance in support of the Paris Agreement.[18]

Objectives of the AC-VC GHG White Paper

- The CEOS Chair commissioned the Atmospheric Composition Virtual Constellation (AC-VC) to write a white paper that defines the key characteristics of a global architecture for monitoring atmospheric CO_2 and CH_4 concentrations and their natural and anthropogenic fluxes from instruments on space-based platforms to:
  - reduce uncertainty of national emission inventory reporting;
  - identify additional emission reduction opportunities
  - provide nations with timely and quantified guidance on progress towards their emission reduction strategies and pledges (Nationally Determined Contributions, NDCs); and,
  - track changes in the natural carbon cycle caused by human activities (deforestation, degradation of ecosystems, fire) and climate change

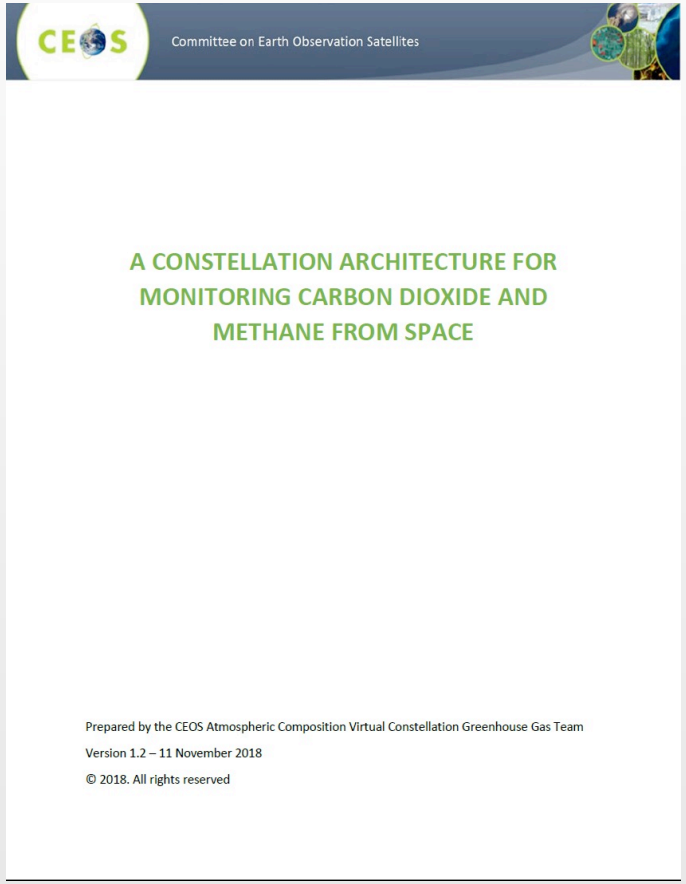
Atmospheric Inventories in the Context of the Paris Agreement

- Atmospheric measurements of CO_2 and CH_4 from ground-, airborne- and space-based sensors could reduce uncertainty in national emission inventory reports by:
  - providing nations with timely, quantified guidance on progress towards their emission reduction strategies and pledges (NDCs)
  - identifying additional emission reduction opportunities;
  - tracking changes in the natural carbon cycle caused by human activities (deforestation, degradation of ecosystems, fire) and climate change
  - Helping to close the carbon budget by providing measurements over ocean and over land areas with poor data coverage (tropical forests, polar regions)

The CEOS Architecture for Monitoring Atmospheric CO_2 and CH_4 Concentrations

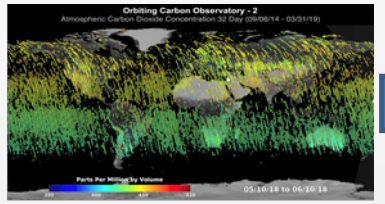
The Committee on Earth Observations Satellites (CEOS) commissioned the Atmospheric Composition Virtual Constellation (AC-VC) team to write a white paper defining a global architecture for monitoring atmospheric CO_2 and CH_4 concentrations from instruments on space-based platforms

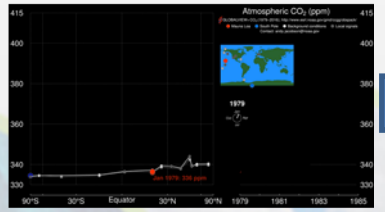
- 166-page document, 88 authors from 47 organizations
- Executive Summary (2 pages)
- Body of report (75 pages)
- Technical Appendices (42 pages)

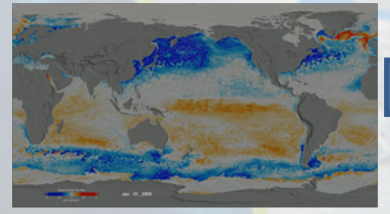


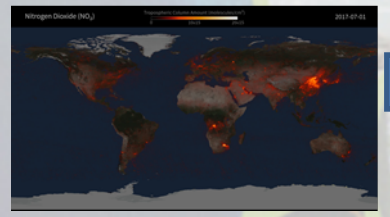
http://ceos.org/document_management/Virtual_Constellations/ACC/Documents/CEOS_AC-VC_GHG_White_Paper_Publication_Draft2_20181111.pdf

Space-based Measurements are Only One Component of an Atmospheric GHG Inventory System









Observations

- **Satellite Measurements of CO_2 and CH_4**
- **Ground and Airborne Measurements of CO_2 and CH_4**
- **Meteorology** Satellite & in-situ
- **Auxiliary Data** Satellite observations of CO, NO_2, clouds, aerosols ...

Prior Information

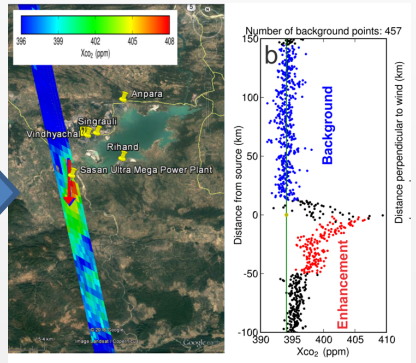
Fluxes, model parameters, emission reports, economic statistics.

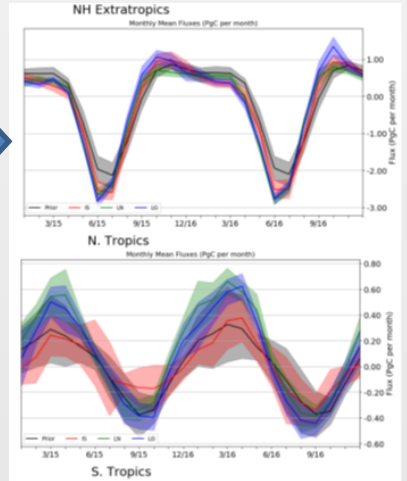
Integration & Attribution

- **Estimation system** Data assimilation and uncertainty estimation
- **Models** Transport, land & ocean carbon cycle, fossil fuel emissions.

Outputs

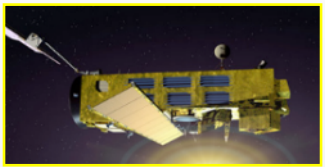
- **CO_2 and CH_4 emissions & removals from Hot-spots** with uncertainties
- **Country/region CO_2 and CH_4 emissions & removals** with uncertainties
- Other Carbon Cycle Products



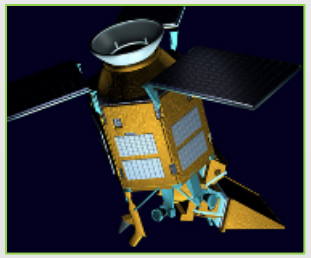


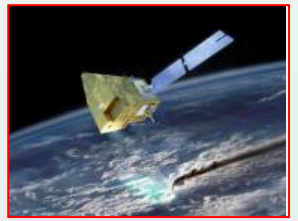
Collecting GHG Observations from Space: The Evolving Fleet

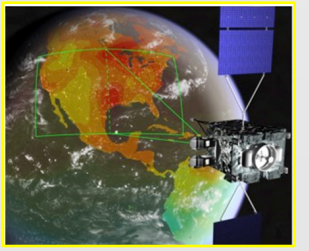
- **Space agencies have supported several pioneering space-based GHG sensors :**
  - ESA's ENVISAT SCIAMACHY,
  - Japan's GOSAT TANSO-FTS, NASA's OCO-2, China's TanSat AGCS, Feng Yun-3D GAS and Gaofen-5 GMI, Copernicus Sentinel 5 Precursor TROPOMI.
- **Other sensors just added to the fleet:**
  - Japan's GOSAT-2 TANSO-FTS-2 and NASA's ISS OCO-3
- **Others are under development:**
  - CNES MicroCarb, CNES/DLR MERLIN, NASA's GeoCarb





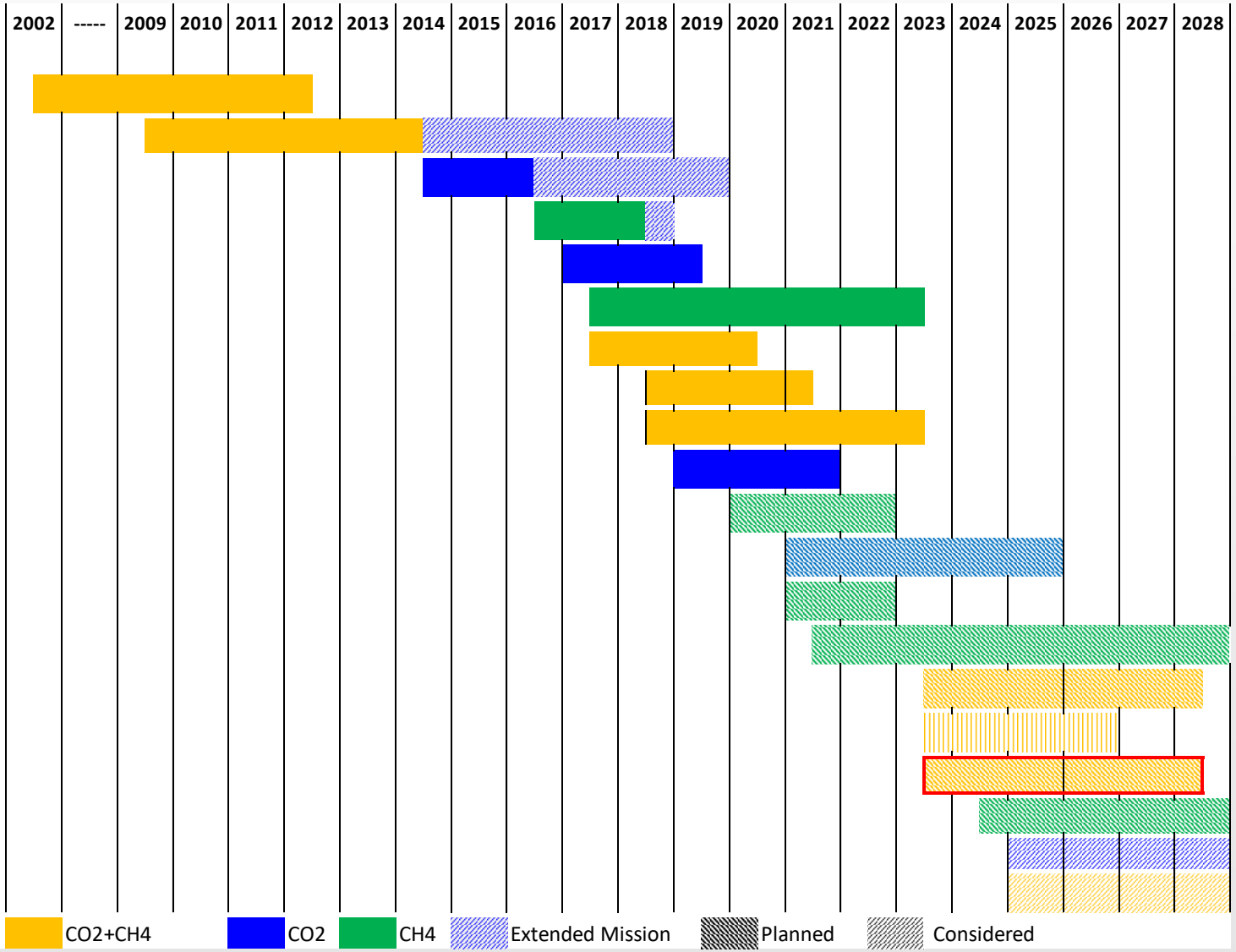


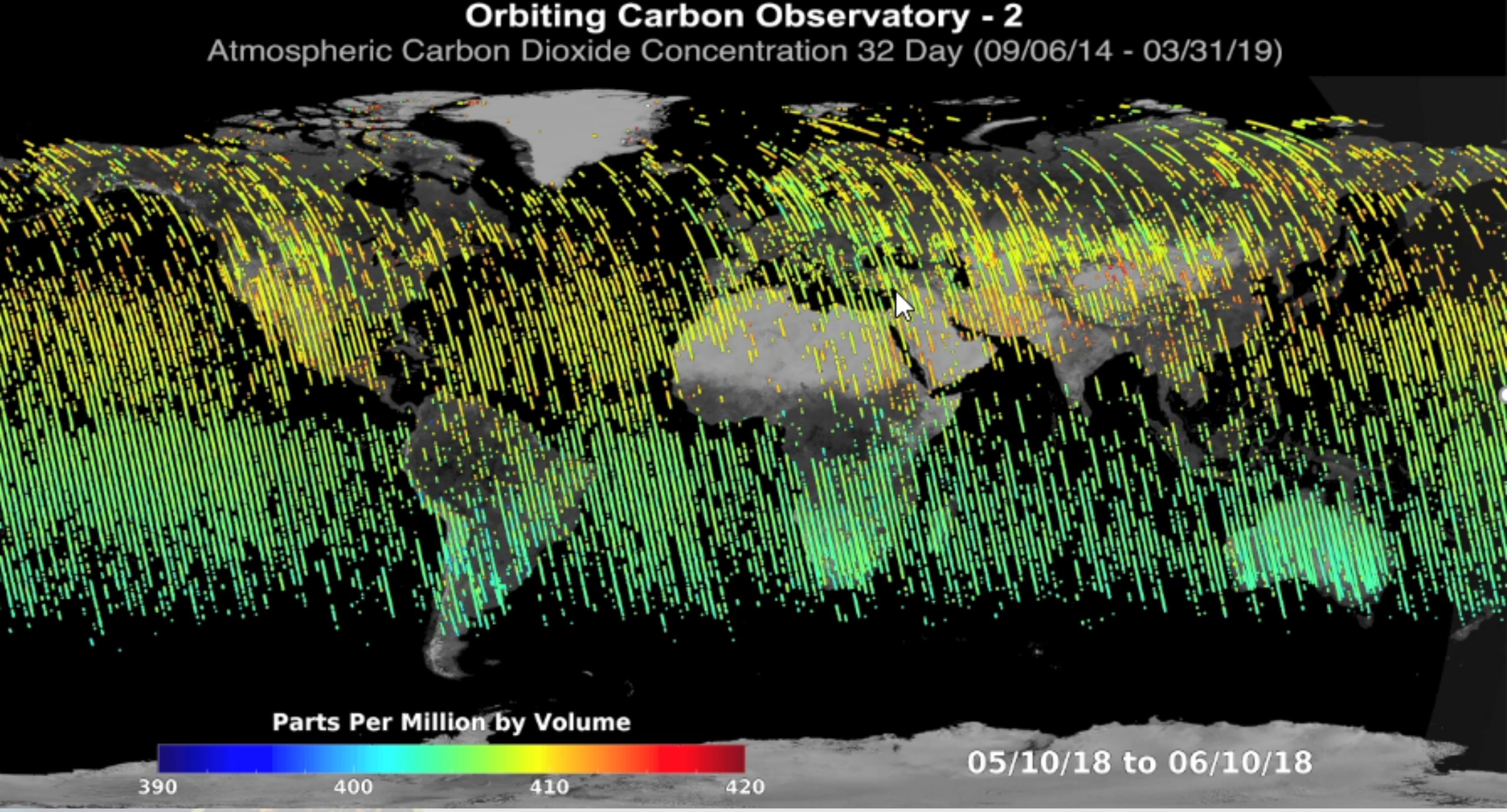





The GHG Constellation Time Line

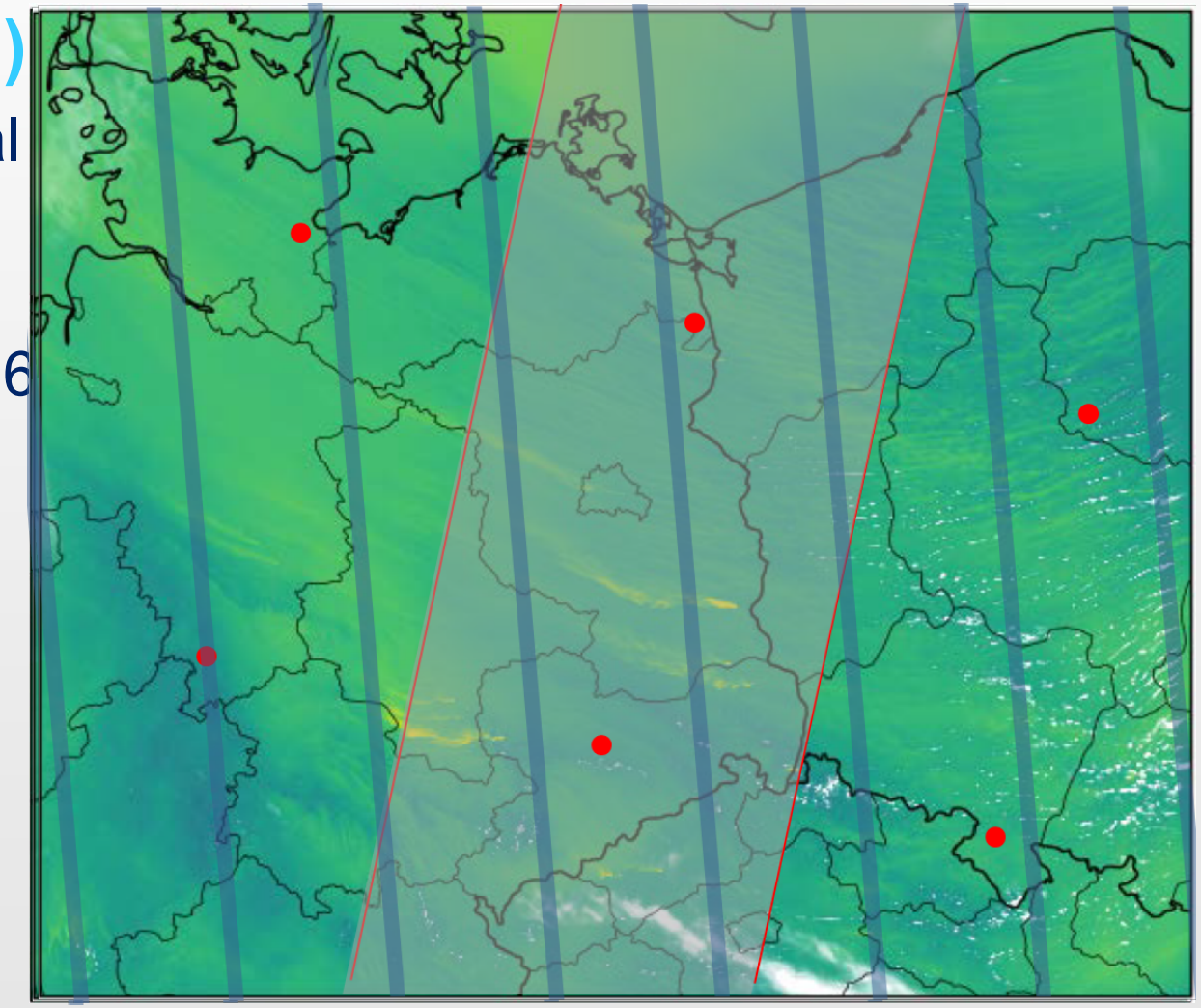
Satellite, Instrument (Agencies)	CO_2	CH_4	Swath	Sample
ENVISAT SCIAMACHY (ESA)	●	●	960 km	30x60 km^2
GOSAT TANSO-FTS (JAXA-NIES-MOE)	●	●	3 pts	10.5 km (d)
OCO-2 (NASA)	●		10.6 km	1.3x2.3 km^2
GHGSat (Claire)		●	12 km	0.0004 km^2
TanSAT (CAS-MOST-CMA)	●		20 km	1x2 km^2
Sentinel 5P TROPOMI (ESA)		●	2600 km	7x7 km^2
Feng Yun 3D GAS (CMA)	●	●	7 pts	10 km (d)
GaoFen-5 GMI	●	●	5-9 pts	10 km (d)
GOSAT-2 TANSO-FTS (JAXA-MOE-NIES)	●	●	5 pts	10.5 km (d)
OCO-3 (NASA)	●		11 km	4 km^2
Bluefield Technologies		●	25x20 km	0.0004 km^2
MicroCarb (CNES)	●		13.5 km	40 km^2
MethaneSAT (EDF)		●	200 km	1 km^2
MetOp Sentinel-5 series (Copernicus)		●	2670 km	7x7 km^2
Feng Yun 3G (CMA)	●	●	100 km	< 3 km^2
GEOCARB (NASA)	●	●	2800 km	3x6 km^2
GOSAT-3 (JAXA-MOE-NIES)	●	●	TBD	TBD
MERLIN (DLR-CNES)		●	100 m	0.14 km (w)
TanSat-2 Constellation	●	●	3x100 km	2x2 km^2
CO2 Sentinel (Copernicus)	●	●	3x250 km	2x2 km^2




Orbiting Carbon Observatory - 2
Atmospheric Carbon Dioxide Concentration 32 Day (09/06/14 - 03/31/19)
Parts Per Million by Volume
390
400
410
420
05/10/18 to 06/10/18

Next Steps: Operational LEO GHG Constellations

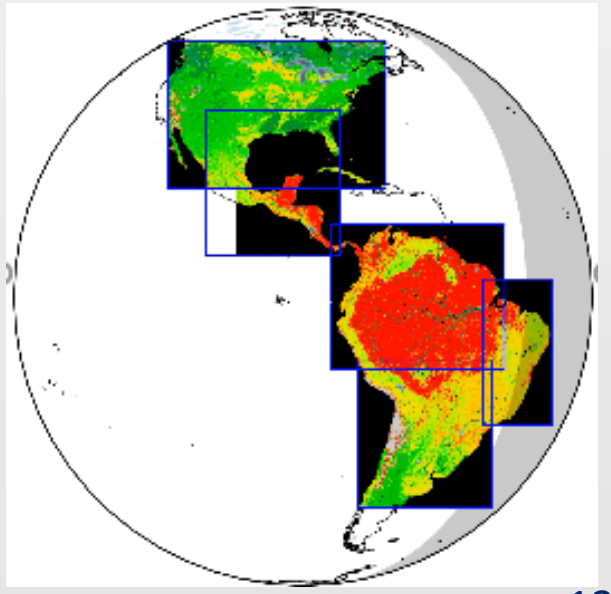
- **Copernicus CO_2 Sentinel (2025+)**
  - 3 or 4 LEO satellites in an operational GHG constellation
  - Primary spectrometer measures O_2 (0.76 μm A-band), CO_2 (1.61 and 2.06 μm), CH4 (1.67 μm)
  - Ancillary instrument include
    - o NO_2 (0.450 μm) at a spatial resolution of 2 km x 2 km along a 200-300 km swath for plumes
    - o A cloud/aerosol multi-angle polarimeter



A Candidate Operational CO_2/CH_4 Constellation Architecture

The coverage, resolution, and repeat frequency requirements could be achieved with a constellation that incorporates:

- A constellation of 3 (or more) satellites in LEO with
  - A broad (> 250 km) swath with a footprint size < 4 km^2
  - A single sounding random error near 0.5 ppm, and vanishing small regional scale bias (< 0.1 ppm)
  - Ancillary sensors to identify plumes (CO, satellites NO_2)
- A constellation with 3 (or more) GEO satellites
  - Stationed over Europe/Africa, Americas, and East Asia
  - Monitor diurnally varying processes (e.g. rush hours, diurnal variations in the biosphere)



Developing Atmospheric GHG Inventories

The CEOS AC-VC GHG White Paper recommends the following approach:

1. Refine requirements and implementation plans for atmospheric flux inventories
   - Foster collaboration between the space-based and ground-based GHG measurement and modeling communities and the bottom-up inventory and policy communities
2. Produce a prototype atmospheric CO_2 and CH_4 flux inventory that is available in time to inform the bottom-up inventories for the 2023 global Stocktake
   - Exploit capabilities of CEOS), Coordination Group on Meteorological Satellites (CGMS) and the WMO Integrated Global Greenhouse Gas Information System (IG3IS)
3. Use the lessons learned from this prototype flux product to refine the requirements for a future, purpose-built, operational, atmospheric inventory system
   - more completely addresses the inventory process in time to support the 2028 global Stocktake.

Endorsement and Next Steps

- The 2018 CEOS Plenary endorsed the AC-VC GHG White Paper
  - The Plenary confirmed CEOS interest in continuing collaboration with CGMS through a specific task in WGClimate on GHG monitoring, with dedicated resources and activities based on the mapping table of the actions identified in the Way Forward chapter of the report
    - The 3-point plan and activities are interpreted as recommendations to the CEOS Agencies
  - Plenary also endorsed the revision of the Terms of Reference of the WGClimate to accommodate these changes
  - AC-VC will support GHG constellation development and synergistic GHG and atmospheric composition observations and modelling efforts
  - WGCV will support the definition of the calibration and validation needs
  - The CEOS SIT Chair encouraged the publication of the white paper to facilitate citations and efforts to build on its content
    - WMO and Copernicus have agreed to jointly publish the white paper
    - Publication date ~June 2019